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मानक

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Mazdoor Kisan Shakti Sangathan

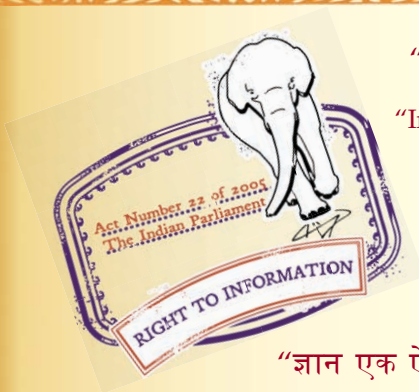
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“पुराने को छोड़ नये के तरफ”

Jawaharlal Nehru

“Step Out From the Old to the New”

IS 15662 (2006): Geological exploration for gravity dams and overflow structures - Code of practice [WRD 5: Geological Investigation and Subsurface Exploration]



“ज्ञान से एक नये भारत का निर्माण”

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“Invent a New India Using Knowledge”



“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”

Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

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IS 15662 : 2006

भारतीय मानक
भाराश्रित बाँधों तथा उत्प्लावी संरचनाओं के
भूगर्भीय अन्वेषण — रीति संहिता

Indian Standard
GEOLOGICAL EXPLORATION FOR GRAVITY DAMS
AND OVERFLOW STRUCTURES —
CODE OF PRACTICE

ICS 93.020

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BUREAU OF INDIAN STANDARDS
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May 2006

Price Group 3

AMENDMENT NO. 1 DECEMBER 2007
TO
IS 15662 : 2006 GEOLOGICAL EXPLORATION FOR
GRAVITY DAMS AND OVERFLOW
STRUCTURES — CODE OF PRACTICE

(Page 1, clause 2) — Substitute 'IS 15686 : 2006 Recommendations for the preparation of geological and geotechnical maps for river valley projects' for 'IS 6065 (Part 1) : 1985 Recommendations for the preparation of geological and geotechnical maps for river valley projects : Part 1 Scales (*first revision*)'.

[Page 4, clause 7.2.1(b)] — Substitute 'Modulus of Elasticity and Poisson's Ratio' for 'Modulus of elasticity'.

[Page 4, clause 7.2.1(e)] — Substitute 'Shear and Compression Wave Velocities' for 'Shear and compressional ultrasonic velocities'.

[Page 4, clause 7.2.1(g)] — Substitute 'Swelling characteristics' for 'Swelling'.

(Page 4, clause 7.2.1) — Insert the following after 7.2.1(h):

'j) Tensile Strength (Direct/ Indirect)'.

[Page 4, clause 7.2.2(a)] — Insert the following after 'Shear.....and interfaces':

'of rock and construction material of (concrete/ masonry) dams and overflow structures'.

[Page 4, clause 7.2.2(b)] — Substitute 'Modulus of deformation (along different orientations)' for 'Modulus of deformation'.

(Page 5, clause 7.4) — Substitute the following for the existing clause:

'A bankable DPR should be prepared only after completing the detailed investigation/explorations as stated in above clauses and no scope should be left for any change in the project layout'.

(WRD 5)

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Geological Investigations and Subsurface Exploration Sectional Committee had been approved by the Water Resources Division Council.

Keeping in view the thrust on full utilization of hydropower potential available and enhancement of irrigation capacity as well as control of flood situations in the country today, a number of projects are under way involving construction of gravity dams and overflow structures. It is of paramount importance that the potential sites be thoroughly investigated and explored so that, during construction, chances of geological surprises are substantially minimized or avoided. One of the major requirements in planning, designing and construction of gravity dams and overflow structures is proper and adequate geological exploration, both surface and subsurface, based on state-of-the-art techniques in order to have a rapid, economical and dependable pre-investment evaluation.

It is necessary that a uniform and consistent approach be followed while carrying out geological explorations at the project sites so that the frame of reference of the investigation covers all requisite aspects.

The composition of the Committee responsible for the formulation of this standard is given in Annex A.

It has been assumed in the formulation of this Indian Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people, for whose guidance it has been prepared.

Indian Standard

GEOLOGICAL EXPLORATION FOR GRAVITY DAMS AND OVERFLOW STRUCTURES — CODE OF PRACTICE

1 SCOPE

This standard lays down guidelines for the requirement and extent of geological explorations to be carried out for gravity dams and overflow structures in order to evaluate geological and geomechanical characteristics of dam foundations and abutments, for evolving safe and economic designs for construction of these structures. For achieving this objective, guidelines have been given in this standard. However, special explorations may have to be carried out, if extraordinary geological conditions, such as landslide, subsidence, caverns major fault/shear zones, excessive spring flow, gas emanations, etc, are encountered during preliminary investigations. Significance of such adverse geological features in relation to the proposed structure is to be thoroughly understood for estimation of the magnitude of the problem and for devising appropriate treatment/remedial measures.

2 REFERENCES

The following standards contain provisions which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

<i>IS No.</i>	<i>Title</i>
6955 : 1973	Code of practice for subsurface exploration for earth and rockfill dams
6065 (Part 1) : 1985	Recommendations for the preparation of geological and geotechnical maps for river valley projects: Part 1 Scales (<i>first revision</i>)

3 GENERAL CONDITIONS

3.1 The term geological exploration, as used herein, covers all types of explorations, both surface and subsurface, to be carried out for determination of the nature and disposition of geological formations and structures at/or near the proposed site of gravity dam and overflow structure.

The type and extent of geological explorations should be

commensurate with the size and type of the dam and overflow structure and foundation conditions and the status of existing information. They should cover adequate area around the dam and specified depths as given in 6.1. The explorations should be rationally planned with the aim to collect adequate information.

All significant geological and structural features affecting the feasibility of a gravity dam site, particularly those which require remedial treatment, should be clearly known in advance, that is, before detailed design and construction. As such the geological exploration should be focused on highlighting the adverse effects of geological and structural features with reference to competency of the foundation and abutments. A complete programme of geological exploration should be able to provide required information regarding the following:

- a) Types of lithological units present in the foundation and abutments; their disposition, succession, thickness and areal extent should be shown in the detailed geological maps and sections on specific scales.
- b) Characteristics of significant geological and structural features such as bedding/foliation, joints, fissures, folds, faults, shear zones, cavities, dykes and their influence on structural instability of the abutments and foundation.
- c) Extent and thickness of overburden and the type of underlying bedrock, its disposition and depth of weathering.
- d) Engineering properties of the overburden and rock mass.
- e) Geological attributes and related features contributing to landslide and subsidence hazards.
- f) Possible instability due to glacial and fluvial material, overburden covered hill slopes etc, should be indicated. In case of dam abutments structural mapping of hill slopes should be carried out to examine active or potential landslides — debris or rockfall.
- g) Location of dam in mountainous areas should take into account the possibility of avalanches affecting the stability of structures.
- h) Identification of tectonic features and active faults

in and around the proposed site, for seismotectonic evaluation of the area.

3.2 The extent of geological explorations required for gravity dams and overflow structures of a given size varies from site to site, depending on the topographic variations and subsurface geological conditions and cannot be fully visualized in advance. Before undertaking any geological investigation, relevant available information and material such as topographical maps on different scales (1 : 50 000 to 1 : 1 000 scale), regional geological maps, tectonic maps, hydrogeological maps, available literature, reports on geology, areal photographs, satellite imageries, etc, of the project area should be studied. The geological explorations are planned in stages and the details of the surface and subsurface geological conditions are garnered progressively, as the exploration proceeds.

4 STAGES OF GEOLOGICAL EXPLORATIONS

Geological explorations for engineering projects are subdivided into stages, namely:

- a) Reconnaissance or pre- : PFR stage
feasibility stage
- b) Preliminary investigation : FR stage
or feasibility stage
- c) Detailed investigation or : Bankable DPR stage
DPR stage
- d) Construction stage : During construction

Systematic geological investigations sequentially proceed in stages, which generally overlap from one stage to another.

The general practice followed earlier was that the detailed project reports (DPRs) were generated after the preliminary investigation or feasibility stage and based on these reports, conceptual designs were formulated. Many times, changes were necessitated in detailed design consequent to availability of complete geological data during pre-construction stage explorations. Such revisions in detailed design, however, may result in major changes in the quantities, treatment measures and hence the cost and duration of construction. Thus, the bankable DPR should be prepared after completing the pre-construction stage investigations. In fact the above investigation stages, excluding the construction stage, when merged will form the basis of investigations in the preparation of DPR.

5 RECONNAISSANCE OR PRE-FEASIBILITY STAGE (PFR STAGE)

This stage comprises selection of some suitable preferred sites on the basis of regional and local geology, topographic expression and anticipated depth to bedrock. This will consist of general field inspection of all alternative sites by an engineering geologist for the overall

assessment of the geology of the site and general foundation conditions. The geological, topographical and techno-economic aspects will determine the selection of the most promising sites among all alternatives during this stage.

5.1 Data Collection and Desk Study

Data collection and desk study are essential prerequisites before undertaking the reconnaissance visit to the area of interest and identification of alternative sites for the proposed structures. At this stage, it is essential to collect all available geological data; geological maps and published literature etc, and carry out desk study so as to bring out a comprehensive regional as well as local geological picture of the project area.

Normally, a geological map on 1 : 50 000 or on 1 : 25 000 scale with contour interval of 20 m to 40 m is available with national/state level scientific organizations, such as Geological Survey of India (GSI)/Directorate of Geology and Mining (DGM) of the States. Satellite imageries are available from National Remote Sensing Agency (NRSA). In addition, aerial photographs should also be studied for photo geological interpretations.

Available data on geological explorations, such as pitting, drilling, drifting, geophysical surveys etc, if done earlier in the project area, should also be collected. The available geological maps showing the locations of these investigations and the related geological profiles should be studied. This exercise helps in identifying the data gap and for planning further explorations to fill the gaps, if any.

5.2 Output of Desk Study

The desk study of the available data will bring out the following:

- a) General geological, tectonic and geomorphological setup of the project area;
- b) Seismotectonic evaluation of the area for designating its seismic hazard potential;
- c) Disposition of the geological features like conformity, nonconformity, faults, fractures, shear zones, sills, dykes, etc, confirmed and inferred outcrops on the geological map of the project area;
- d) Distribution of bedrock, slump mass and overburden on the geological map of the project area; and
- e) Location of landslide, subsidence, slideprone areas, avalanches, neotectonic activities, etc, on the geological map.

The reconnaissance traverses taken by engineering geologists in the proposed area to examine the suitability of preferred site for dam and other appurtenant structures in the back-

drop of the information collected on geological and topographical characteristics of alternative sites will bring out the following details:

- a) General geological maps and sections,
- b) Geological description of project area,
- c) Geological appreciation, and
- d) Tentative layout of the proposed dam.

A programme of surface and subsurface explorations should be worked out for the preferred site to establish the inferred and required engineering geological characteristics of the project area.

6 PRELIMINARY INVESTIGATION OR FEASIBILITY STAGE (FR STAGE)

During this stage, the engineering geological data of the most suitable and preferred dam locations is collected to formulate the project layout. The coverage of geological exploration should be adequate for assessing the technoeconomic feasibility of gravity dam and overflow structure.

6.1 Methods of Geological Investigation/Exploration

All the preferred locations identified during reconnaissance or pre-feasibility stage should be more intensively explored geologically. The exploration should cover adequate area, as per the need of the site so as to minimize uncertainties, that is, geological surprises. The exploration should comprise the following:

- a) Surface geotechnical mapping.
- b) Exploration by test pits, trenches, drifts and shafts.
- c) Exploration by drilling methods.
- d) Exploration by geophysical methods including seismic/resistivity surveys and Ground Penetrating Radar (GPR) Surveys.
- e) Determination of the water table depth and evaluation of field permeability by water percolation tests.
- f) Observation of temperature, pressure and discharge of springs met on the surface or in exploratory drillings, trenches, etc.
- g) Standard penetration test (SPT) and field density tests in overburden.

6.2 Surface Geological Mapping

The sites of gravity dam and its appurtenant structures should be geologically mapped on 1 : 1 000 scale with contour interval of 1 m to 5 m. Extent of geological mapping should cover an area equal to twice the height of the dam both towards the upstream and the downstream. The mapping should extend up to 100 m above the top of the dam in areas of immature topography and 25 m in the

area of mature topography. Geological mapping should be extended to assess instability of slopes for providing special slope treatment. The geological/geotechnical map so prepared should bring out the following:

- a) Strike extension of various lithological units present in the area.
- b) Susceptibility to weathering of each unit.
- c) Structural discontinuities and their characteristics, such as joints, fractures, cleavages, slip planes, shear zones, faults, folds and their permeability characteristics.
- d) Slope characteristics, such as covered area, creep material, slide/subsidence/collapse features.
- e) Groundwater characteristics and their range of fluctuation.
- f) Location of springs, their temperature, discharge, etc.

6.3 Subsurface Geological Exploration

Subsurface geological exploration should be done using the methods given in 6.1 or 6.2 or by a combination of all or some of them, depending upon requirement of the area and proposed size of structure.

For the entire dam area and especially the areas covered by debris or river-borne material/terrace deposits, geophysical surveys including GPR Surveys should be carried out for evaluating depth and nature of bedrock along with ground water level.

For dams up to 30 m height exploration by trial pits, trenches and drill holes should be sufficient. For dams up to 100 m height and above, additional exploration by drifts and shafts may be required depending upon the geological complexity of the site.

Subsurface exploration should establish:

- a) Depth to bedrock or thickness of overburden and weathering limit.
- b) Lithological characters of various rock units and their significance to dam and appurtenant structures.
- c) Limit of slump joints and glide cracks, if any.
- d) Nature, spacing and continuity of prominent joints, slip planes, minor and major shear zones, etc.
- e) Depth of water table.
- f) Permeability of strata.

The features given in 6.1 to 6.3 should be recorded in the course of investigation at feasibility stage.

6.4 Feasibility Report

When the feasibility stage investigations have been

completed at the selected dam site, all geological/geotechnical data should be analysed and synthesised and a feasibility stage report prepared giving details of the following:

- a) Geological plan of the dam site showing outlines of the dam body.
- b) Geological sections along the dam axis.
- c) Developed geological sections of test pits, trenches and drifts.
- d) Drill hole logs and photographs of cores.
- e) Field and laboratory test results.
- f) Geological evaluation of the proposed dam foundation.

7 DETAILED INVESTIGATION OR DPR STAGE

The geological exploration, both surface as well as subsurface, which is required to be done at this stage are in addition to the already carried out explorations; hence, the location, depth, orientation, etc, of subsurface geological explorations are guided by the geological complexity of dam site as understood during feasibility stage and design characteristics of the dam and its appurtenant structures. It is advisable that explorations under this stage should be planned and executed in close cooperation and interaction between engineering geologist and design engineers.

7.1 Detailed Subsurface Geological Exploration

7.1.1 The drill hole should be drilled along the proposed axis of the dam at 50 - 150 m interval or less with a minimum number of three to five holes in gorge portion and additional two on each abutment parallel to the flow for establishing bedrock and for obtaining cores for determining physical and engineering properties by laboratory tests. In such drill holes the water table, if encountered, should be carefully recorded. In addition, cyclic percolation tests should also be performed for determining the permeability of the foundation material. Further at least two more drill holes should be done at the toe of the dam and one hole in the energy dissipation structure immediately after the spillway. It is essential that drilling be done for a depth of 10 m into fresh rock (proved by geophysical or any other method). Out of the minimum number of three to five drill holes in the gorge portion and additional two on each abutment parallel to the flow, about two holes to be extended (equal to the maximum height of the dam in the absence of rock at higher elevation) in the gorge portion and one each in abutment. For the diversion tunnel also, up to three drill holes may be drilled with one each at the portal and the third one suitably placed along the tunnel alignment depending upon the geology and topography.

7.1.2 When the geological conditions under a river bed

cannot be established by vertical drilling, an inclined drilling is to be made downwards from each bank with the drill holes crossing each other under the river bed. At times it is advantageous to go for under river bed drift to confirm any suspected faults/shear zones.

7.1.3 For a dam up to 50 m height, one drift on either bank with cross cuts should be excavated at or near mid height of the dam. For a dam up to 100 m height two drifts on either bank with cross cuts are recommended at or near 1/3rd and 2/3rd height of the dam. For a dam more than 100 m high, three or more drifts on either bank with cross cuts are recommended. However, the length of the main drift and the cross cuts will depend upon the dimension of the structure (dam section across and along the flow) at that particular elevation, meaning thereby that the length of the main drift and cross cuts will be more near the base and reducing gradually towards the top of the dam. The length of the drift should be decided by the Engineering Geologist as per design requirement, which in turn depend on the height of the dam and quality of the rockmass. These drifts can be utilized for various purposes namely, inspection, drainage and grouting at a later stage.

7.1.4 The groutability of foundation through trial grouting of the specific section, in a set pattern, should also be tested during this stage.

7.2 Geotechnical Properties of Foundation Medium

The geotechnical properties of the foundation medium should be determined by conducting laboratory tests on rock samples as well as by *in-situ* testing on specific locations wherever deemed necessary. The engineering properties given in 7.2.1 and 7.2.2 should be evaluated, considering the necessity in the overall context of the design requirements and the type and height of the dam.

7.2.1 Laboratory Tests

- a) Unconfined compressive strength.
- b) Modulus of elasticity.
- c) Specific gravity and water absorption.
- d) Slake durability index.
- e) Shear and compressional ultrasonic velocities.
- f) Shear strength of infilling material.
- g) Swelling.
- h) Joint stiffness test.

7.2.2 In-Situ Test

- a) Shear strength parameters (cohesion and friction angle) of rockmass, discontinuities and interfaces.
- b) Modulus of deformation.
- c) Seismic wave velocity.
- d) Bearing capacity test.

7.3 At this stage, all data required to provide a fairly clear understanding of the existing geological conditions, at the most favourable site, should be collected for detailed design and preparation of construction drawings. The explorations given below should be carried out at the finally selected site:

- a) Detailed engineering geological mapping on 1 : 1 000 scale with contour interval of 1 m to 3 m besides updating of all geological maps. If there have been changes in the layout, additional areas may have to be covered.
- b) Supplementary or confirmatory subsurface explorations should be done only in grey areas. As such, additional holes are to be drilled, if they are absolutely essential. Permeability tests should be conducted in all drill holes.
- c) One or two drifts may additionally be made in the abutment depending on site condition. For diversion tunnel, two drifts of 30 m to 50 m length may be done at inlet and outlet portals, if required, depending on geological conditions.
- d) Additional geophysical explorations wherever required to define in greater details the subsurface conditions.
- e) Special field tests such as blasting tests, *in-situ* shear tests and vibration study, etc, wherever found necessary, should be done.
- f) Groutability of foundation, through test grouting of specific section, should also be studied.

- g) Geohydrological characteristics of the foundation should be defined.
- h) Geotechnical evaluation of foundation/abutment treatment should be made to finalise the treatment plan.

7.4 Bankable Detailed Project Report (DPR)

A bankable DPR should be prepared only after completing the detailed investigation/explorations and no scope for further investigation should be left and the project layout must be taken as final.

8 CONSTRUCTION STAGE

During this stage, large scale geological investigations are carried out to delineate all geological and structural features exposed on the foundation of the dam and its appurtenant structures and to apprise the construction and design engineers regarding rock mass structure and any special geo-structural features like fault zones, deformed/weak zones, breccia zones, shear, etc, which require dental or any other suitable treatment like grouting for strengthening rock mass and making them water-tight. The shear zones, deformed zones or weak zones should be marked with colour paint on the foundation surface. The final foundation grade geological mapping should be done on 1 : 100 scale with 1 m contour interval in grid pattern (2 m × 2 m) using high precision survey equipment like total station. The foundation surface should be properly cleaned by air or water jet before taking up geological mapping which guides the foundation preparation and treatment.

ANNEX A

(Foreword)

COMMITTEE COMPOSITION

Geological Investigation and Subsurface Exploration Sectional Committee, WRD 5

<i>Organization</i>	<i>Representative(s)</i>
Geological Survey of India, Dehra Dun	Dr P. C. NAWANI (<i>Chairman</i>)
Advanced Technology & Engineering Services, New Delhi	Dr V. M. SHARMA
AFCONS, Mumbai	SHRI V. S. KULKARNI SHRI S. V. KAMAT (<i>Alternate</i>)
Central Building Research Institute, Roorkee	SHRI ASHOK KUMAR SHARMA
Central Ground Water Board, New Delhi	Dr S. B. SINGH Dr CHAKRABORTY (<i>Alternate</i>)
Central Mining Research Institute, Roorkee	Dr R. K. GOEL Dr J. K. MOHNOT (<i>Alternate</i>)
Central Soil & Material Research Station, New Delhi	DIRECTOR JOINT DIRECTOR (<i>Alternate</i>)

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<i>Organization</i>	<i>Representative(s)</i>
Central Water & Power Research Station, Pune	DR N. GHOSH DR J. M. SHIRKE (<i>Alternate</i>)
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Consulting Engineering Services (I) Ltd, New Delhi	MANAGING DIRECTOR
Ferro Concrete Construction (India) Pvt Ltd, Indore	SHRI MAHAVIR BIDASARIA SHRI V. K. GEED (<i>Alternate</i>)
Geological Survey of India, Hyderabad	SHRI G. S. MURTHY DR K. K. REDDY (<i>Alternate</i>)
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Irrigation Department, Government of Karnataka, Bangalore	SENIOR GEOLOGIST
Irrigation Department, Government of Maharashtra, Nasik	SUPERINTENDING ENGINEER EXECUTIVE ENGINEER (<i>Alternate</i>)
Irrigation Department, Government of Punjab, Chandigarh	CHIEF ENGINEER SUPERINTENDING ENGINEER (<i>Alternate</i>)
Irrigation Department, Government of Uttar Pradesh, Bareilly	CHIEF ENGINEER SUPERINTENDING ENGINEER (<i>Alternate</i>)
Irrigation Department, Government of Andhara Pradesh, Hyderabad	DIRECTOR
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Larsen & Toubro Ltd, Mumbai	SHRI A. K. ROY SHRI N. K. AGGARWAL (<i>Alternate</i>)
Mineral Exploration Corporation, Nagpur	SHRI D. S. REDDY SHRI C. K. JAIN (<i>Alternate</i>)
Narmada & Water Resources Deptt, Government of Gujarat, Gandhinagar	SUPERINTENDING ENGINEER (DAMS) SUPERINTENDING ENGINEER (GEOLOGY) (<i>Alternate</i>)
National Hydroelectric Power Corporation Ltd, Faridabad	SHRI A. K. SOOD SHRI U. V. HEGDE (<i>Alternate</i>)
National Institute of Rock Mechanics, Karnataka	DR P. C. JHA DR R. N. GUPTA (<i>Alternate</i>)
Skanska Cementations India Ltd, Mumbai	SHRI S. V. WARTY SHRI MANISH KUMAR (<i>Alternate</i>)
BIS Directorate General	SHRI A. M. DAVID, Director (WRD) [Representing Director General (<i>Ex-officio</i>)]

Member Secretary
Ms BHAVANA SHARMA
Assistant Director (WRD), BIS

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